Design of an airfoil insensitive to leading edge roughness

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1.Introduction

During wind turbine operation dirt, salt, erosion or damage can modify the surface of the wind turbine blades, especially at the leading edge. Contamination causes earlier separation, with the consequence of reduction in wind turbine performances. The drop of lift-to-drag ratio due to contamination is inevitable, nevertheless, it can be reduced.

2.Objectives

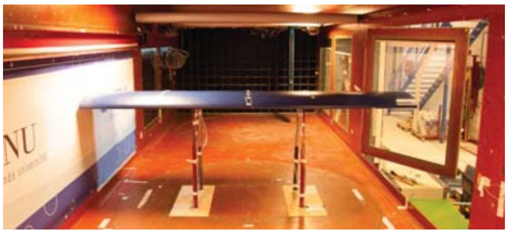
The drop in lift-to-drag can be reduced minimizing the reduction of the maximum lift coefficient ($C_{l,max}$). The main concept behind designing an airfoil with maximum lift coefficient insensitive to leading edge roughness is to shape it such that the transition point at the suction side moves towards the leading edge just before $C_{l,max}$, hence ensuring always a turbulent boundary layer near the leading edge before stall. This should reduce the drop of Cl,max in case of leading edge roughness.

4.Assumptions

- The method of obtaining the lift coefficient from the pressure distribution results the most reliable
- The methods of obtaining the drag coefficient from the wake survey and from the pressure distribution result the most reliable respectively for low and high angles of attack.
- The results of lift and drag coefficients obtained with the balance are used to compare the different experimental set-up. That is the method which is the least time consuming, but least reliable.

3.Methodology

The airfoil was designed and its performances simulated using the program Xfoil. The airfoil was built as a two-dimensional model, with constant chord spanning the whole wind tunnel width.

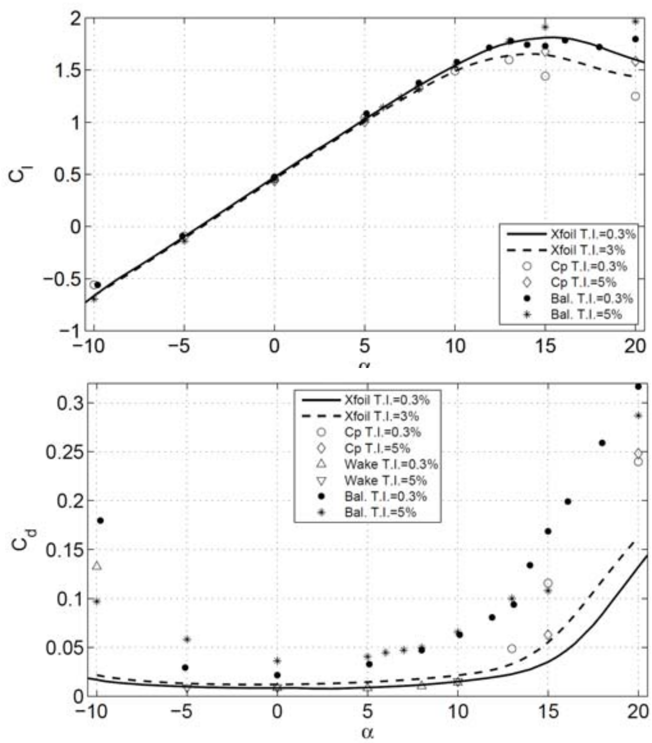


The lift and drag of the wing was measured for different angle of attack, for both clean condition (at turbulence intensities) and with applied roughness of different size and at different position at the leading edge.

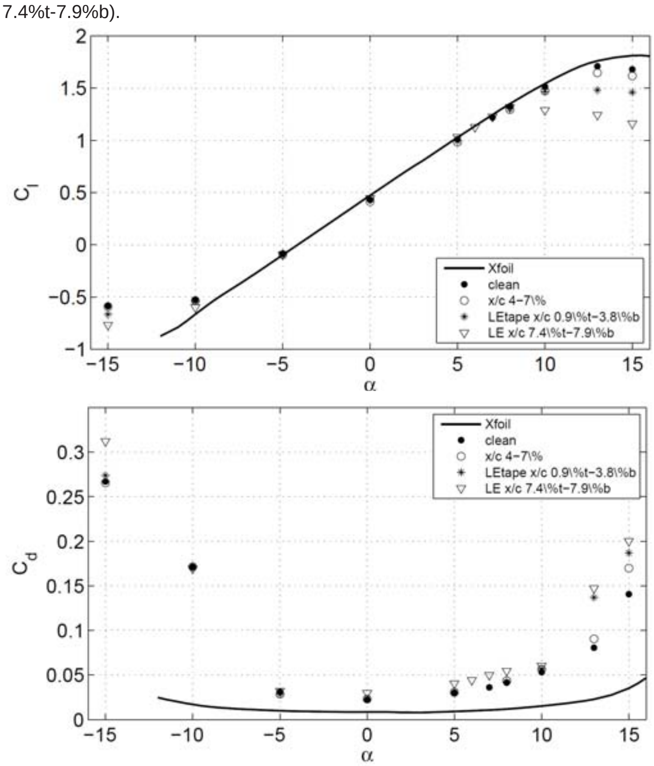
- The lift was measure with both the balance on which the wing was mounted and calculated from the pressure distribution.
- The drag was measured both with the balance, by wake survey and calculated from the pressure distribution.

5.Results

Effect of turbulence. Lift and drag coefficients in function of angle of attack for turbulence intensity T.I.=0.3% (Re=8.6·10^5) and T.I.=5% (Re=7.4·10^5). Numerical results from Xfoil and experimental results from balance (Bal.), pressure distribution (Cp) and wake survey (Wake)



Effect of roughness. Lift and drag coefficients in function of angle of attack for Re=8.7·10^5 obtained with the balance. Grains (size ≈0.5mm) applied on the suction side between 4% and 7% of the chord (x/c 4-7%). Tape applied around the leading edge between 0.9% on the suction side and 3.8% on the pressure side (LEtape x/c 0.9%t-3.8%b). Grains applied around the leading edge between 7.4% on the suction side and 7.9% on the pressure side (x/c 7.4%t-7.9%b).



6.1. Discussion on effect of turbulence

The free stream turbulence has the positive effect of delaying stall. The drag does not increase considerably for low angle of attacks and decreases for high angles, due to the stall delay.

6.2. Discussion on effect of roughness

The aerodynamic characteristics are not affected considerably by distributed roughness of small grain size, if this is applied on the suction side downstream of 4% of the chord. In fact in this case $C_{l,max}$ drops by 4%. This means that the transition occurs naturally very close to the leading edge.

6.References

Bracchi, Tania. "Downwind Rotor: Studies on yaw Stability and Design of a Suitable Thin Airfoil." PhD thesis, 2014. .